



A QCD analysis of ZEUS diffractive data

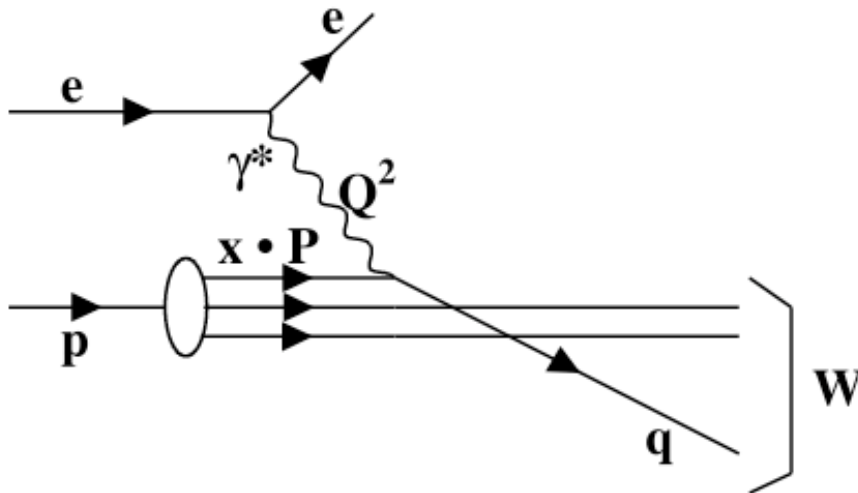
Matthew Wing (UCL)

On behalf of the ZEUS Collaboration

- Introduction and motivation
- Fitting framework and procedure
- Fit results
- Comparison of fits with other data
- Summary

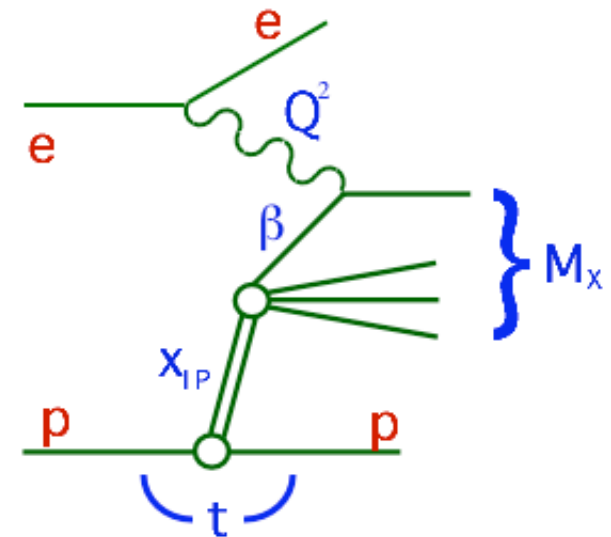
Introduction—what is diffraction ?

Deep inelastic scattering



Parton densities in proton

Diffractive deep inelastic scattering

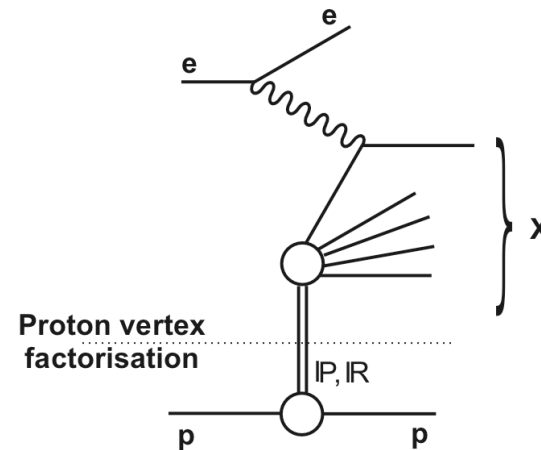
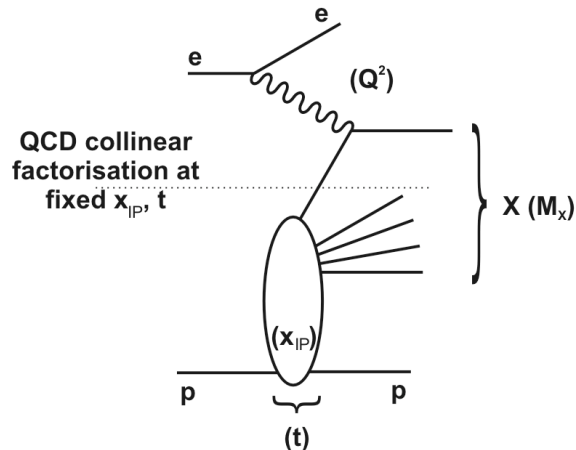


Parton densities in “Pomeron” (*i.e.* when there is a fast proton in the final state)

$$\sigma^{(D)}_{ep \rightarrow eX(p)} \sim f^{(D)}_{i/p} \otimes \sigma_{i\gamma \rightarrow jk}$$

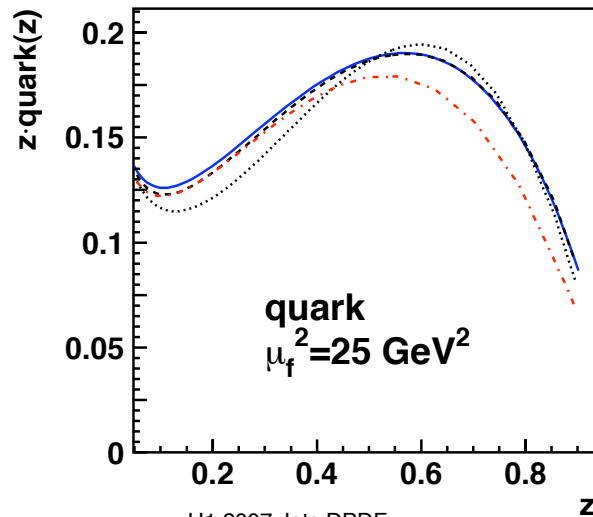
Introduction—why study diffraction ?

- To understand the nature of diffraction, QCD and its description of diffraction
 - Diffraction is a significant fraction of the inclusive cross section.
 - Can pQCD be used to describe diffraction ?
 - Can we think of diffraction in terms of a factorisable structure function and a hard scattering process ?
 - If so, what are the parton distributions (DPDFs) of the structure functions ?

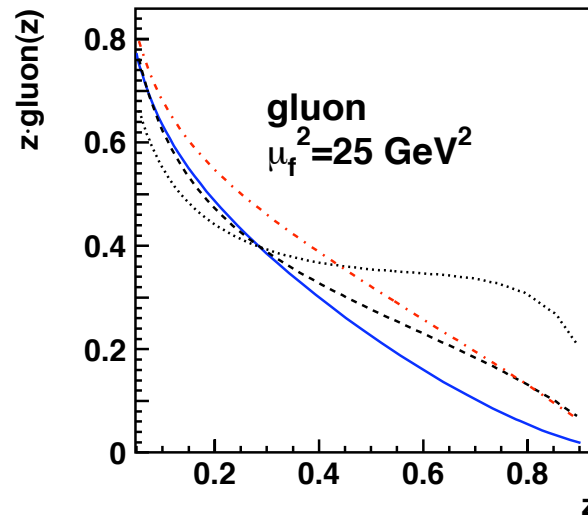


- Will it provide a “smoking-gun” for new physics ?

Introduction—what known and what to improve ?



- H1 2007 Jets DPDF
- ⋯ H1 2006 DPDF fit B
- · - H1 2006 DPDF fit A
- - - Martin, Ryskin, Watt 2006



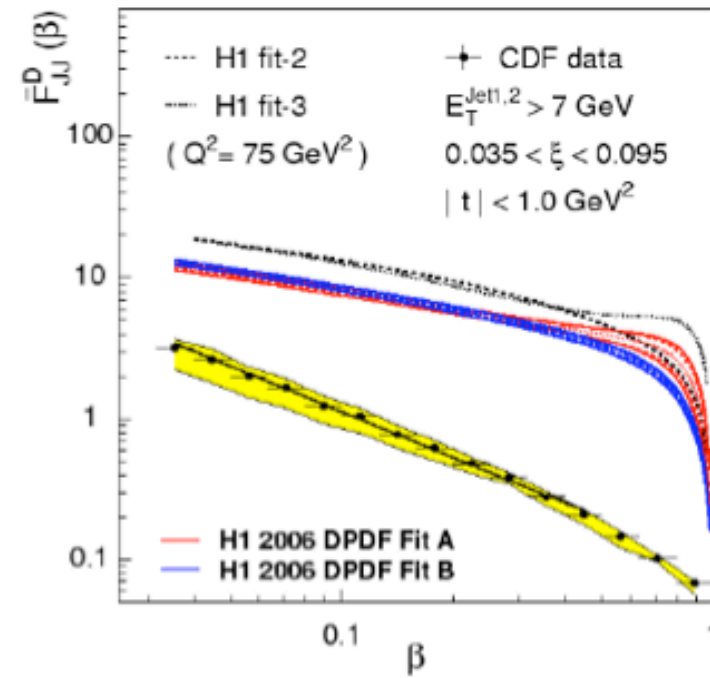
- DIS data can be described by NLO DGLAP fits for DPDFs.
- Tevatron data cannot; MPIs or such need to be invoked.
- Want the best DPDFs we can achieve for LHC predictions.

Have done

- Several groups have extracted DPDFs (H1; Martin, Ryskin and Watt; Golec-Biernat and Luszczak).
- Use of jet data crucial for constraining gluon density.

To improve

- Theoretical assumptions.
- More precise data.



Fitting framework and procedure

Theoretical framework

- DPDFs $f_i^D(z, x_{IP}; Q^2)$ are densities or partons of type i .
 - fractional momentum $z x_{IP}$.
 - probed with resolution Q^2 .
 - a fast proton with fractional momentum $(1 - x_{IP})$.
- Proton-vertex factorisation adopted for x_{IP} dependence.

$$f_i^D(z, x_{IP}; Q^2) = f_{IP}(x_{IP}) f_i(z, Q^2) + f_{IR}(x_{IP}) f_i^{IR}(z, Q^2).$$

Analysis method

- Input parameters fitted to data, minimising a χ^2 , using the “offset” method.
- NLO DGLAP QCD fit.
- Evolution done using QCDNUM and cross checked.
- $\alpha_s(M_Z) = 0.118$, $m_c = 1.35 \text{ GeV}$, $m_b = 4.3 \text{ GeV}$, $Q_0^2 = 1.8 \text{ GeV}^2$.
- Heavy quarks : general-mass variable-flavour-number scheme of Thorne and Roberts.
- Inclusive data : $\mu_R = \mu_F = Q$. Jet data : $\mu_F = Q$, $\mu_R = E_T^{jet}$, use DISENT and NLOJET++.

Fits and data sets

Parametrisation of the DPDFs

$$z f_{d,u,s}(z, Q_0^2) = A_q z^{B_q} (1 - z)^{C_q},$$

$$z f_g(z, Q_0^2) = A_g z^{B_g} (1 - z)^{C_g}.$$

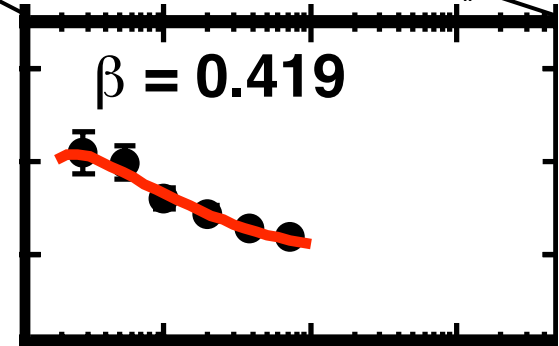
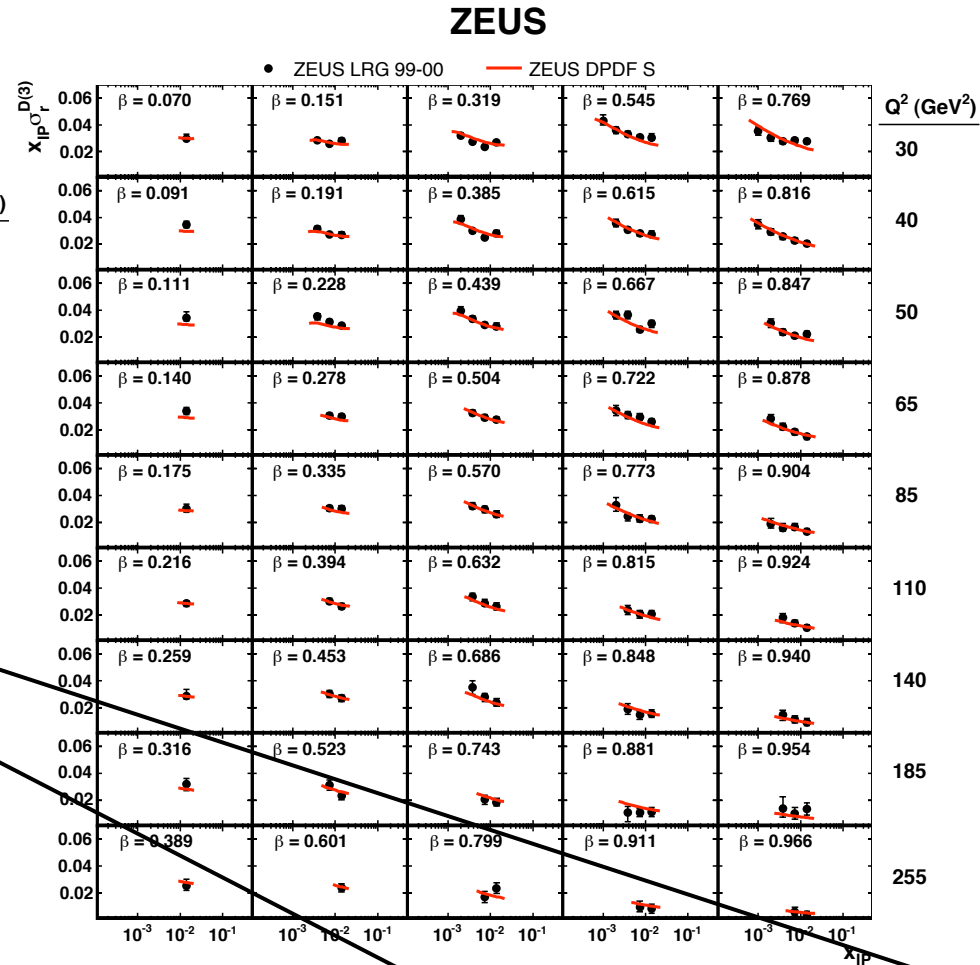
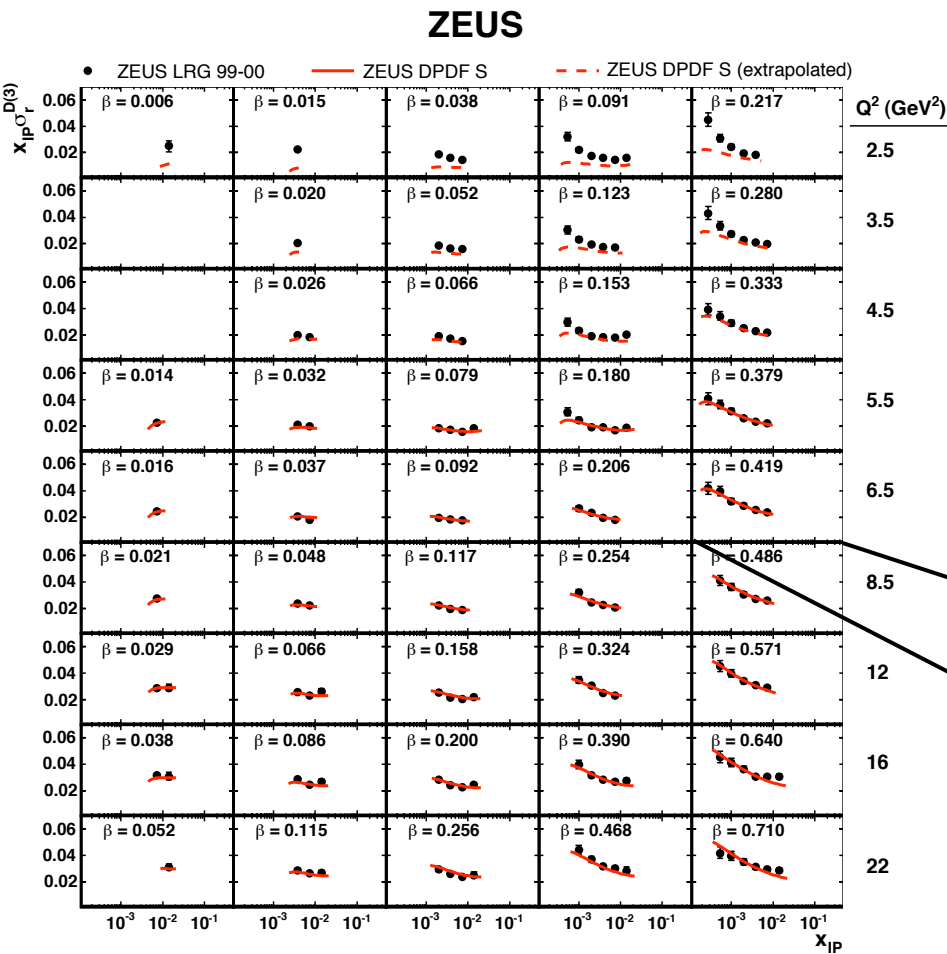
Fit name	Data set	$z g(z)$
ZEUS DPDF S	LRG + LPS	$A_g z^{B_g} (1 - z)^{C_g}$
ZEUS DPDF C	LRG + LPS	A_g
ZEUS DPDF SJ	LRG + LPS + DIS dijets	$A_g z^{B_g} (1 - z)^{C_g}$

In total, 9 free parameters, $A_{q,g}$, $B_{q,g}$, $C_{q,g}$, the Pomeron and Reggeon intercepts, $\alpha_{IP}(0)$ and $\alpha_{IR}(0)$, and normalisation of Reggeon term, A_{IR} .

Data samples

- LRG : $40 < W < 240 \text{ GeV}$, $2 < Q^2 < 305 \text{ GeV}^2$, $2 < M_X < 25 \text{ GeV}$, $0.0002 < x_{IP} < 0.02$
- LPS : $40 < W < 240 \text{ GeV}$, $2 < Q^2 < 120 \text{ GeV}^2$, $2 < M_X < 40 \text{ GeV}$, $0.002 < x_{IP} < 0.1$
- Jet : $100 < W < 250 \text{ GeV}$, $5 < Q^2 < 100 \text{ GeV}^2$, $E_T^{\text{jet}1,2} > 5,4 \text{ GeV}$, $x_{IP} < 0.03$
- But :
 - Overlapping ($x_{IP} < 0.02$) LPS data not used.
 - Only data with $Q^2 > 5 \text{ GeV}^2$ used.

Fit results

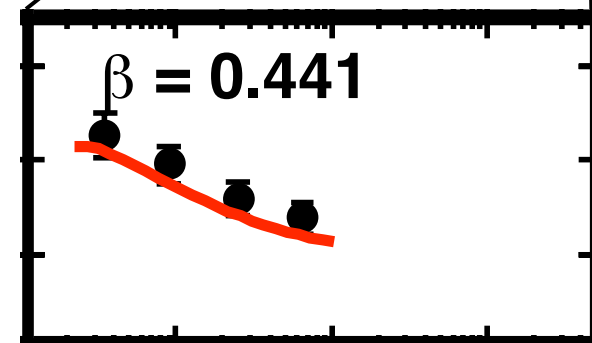
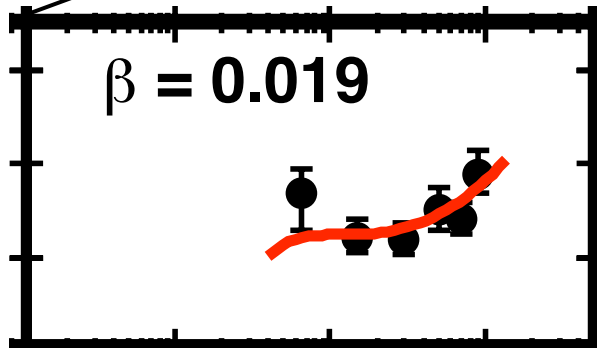
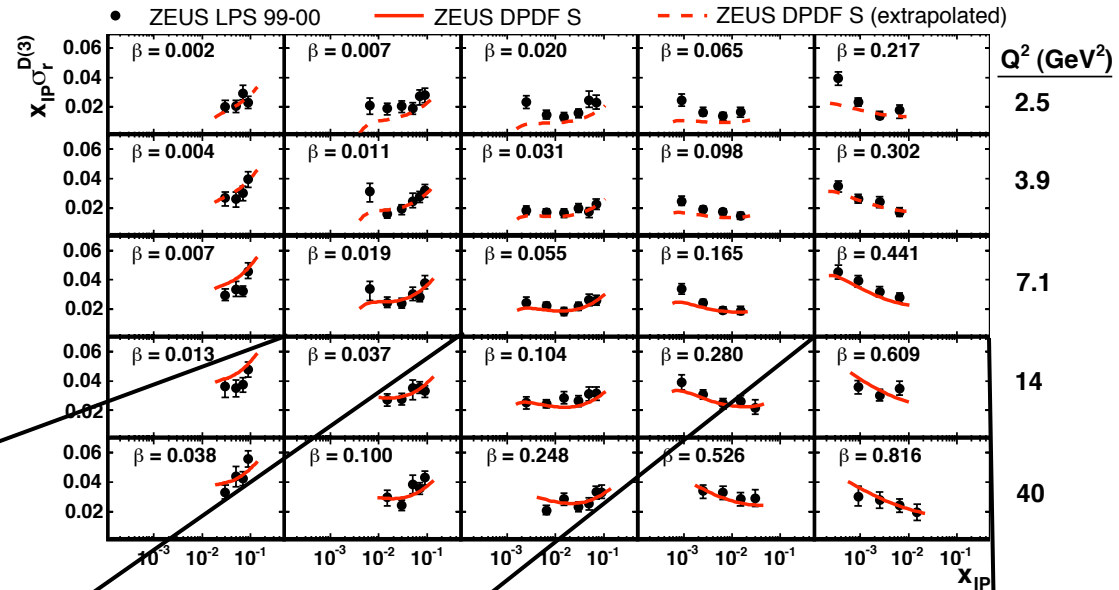


- All fits give a comparably good description of inclusive data.
- Clear deviance of fit and data for $Q^2 < 5 \text{ GeV}^2$.

Fit results

- LPS data likewise well described for $Q^2 > 5 \text{ GeV}^2$.
- Fit above data at low β , where no LRG data.
- Note only $x_{IP} > 0.02$ used; good cross check of fit.
- Values of $\alpha_{IP}(0)$, $\alpha_{IR}(0)$ and A_{IR} consistent with Regge fit.

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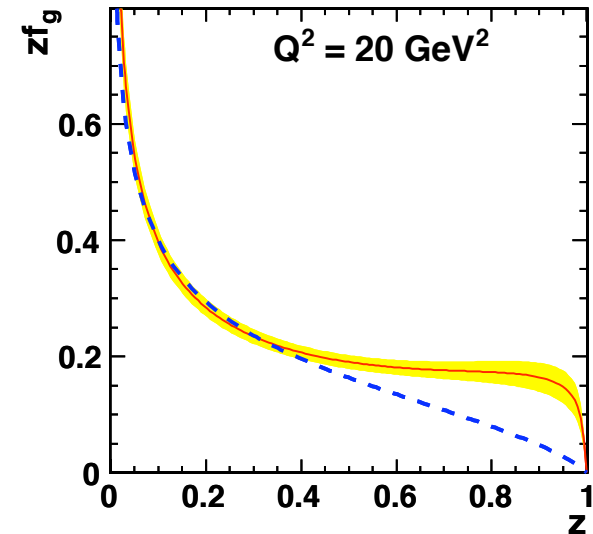
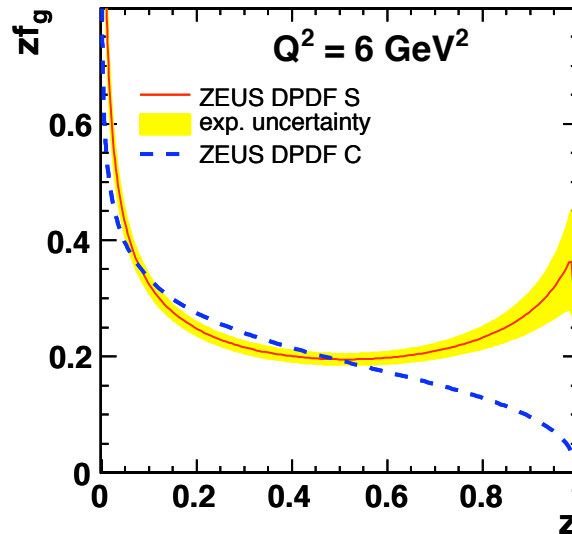
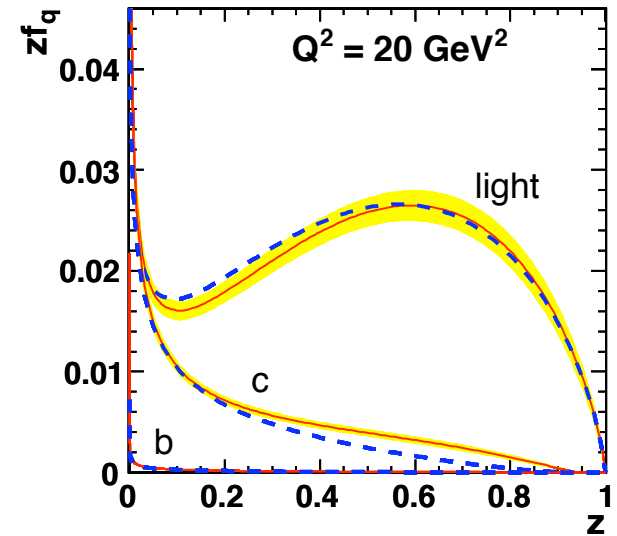
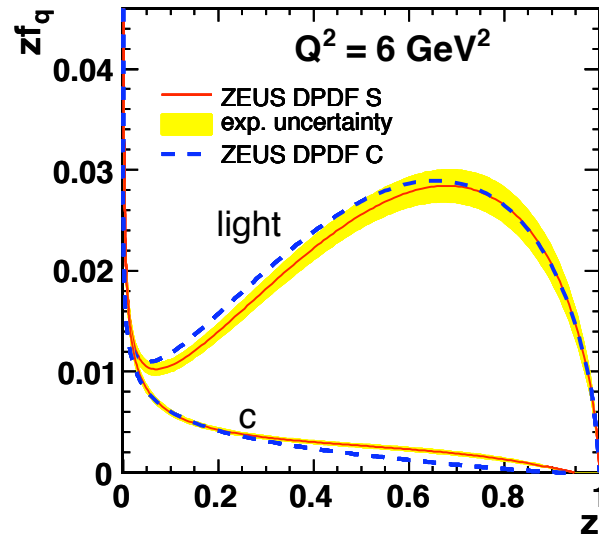
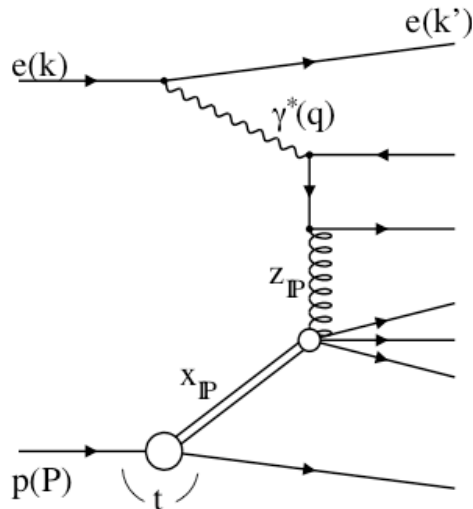
Key message : approach works very well for $Q^2 > 5 \text{ GeV}^2$, however for fully inclusive DIS, DGLAP fits performed down to $Q^2 \sim 2.5 \text{ GeV}^2$.

Resultant DPDFs

Example DPDF distributions

- Smallish uncertainties.
- Quarks similar for two fits.
- Gluons very different for two fits.
- Need jet data to constrain gluon density.

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Comparison with DIS jet data

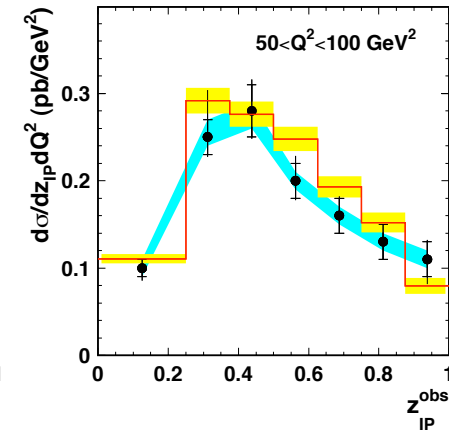
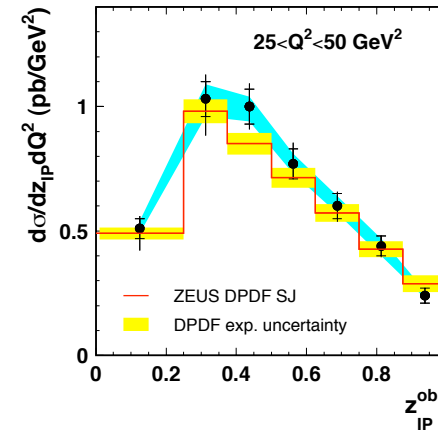
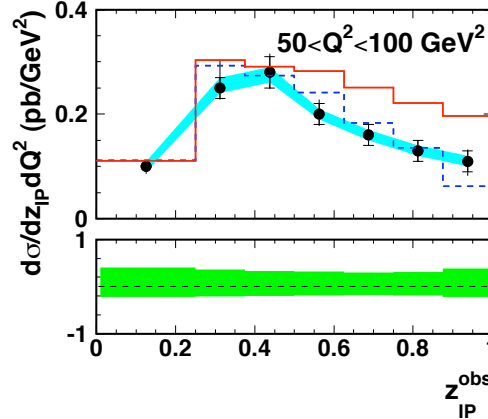
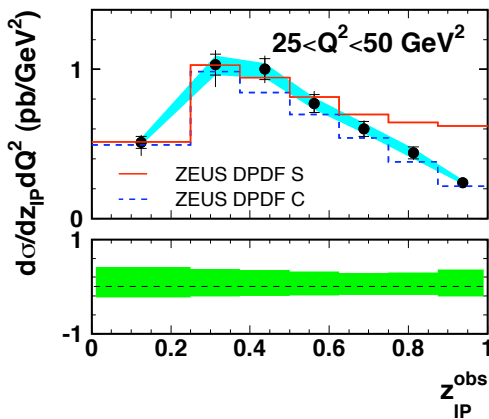
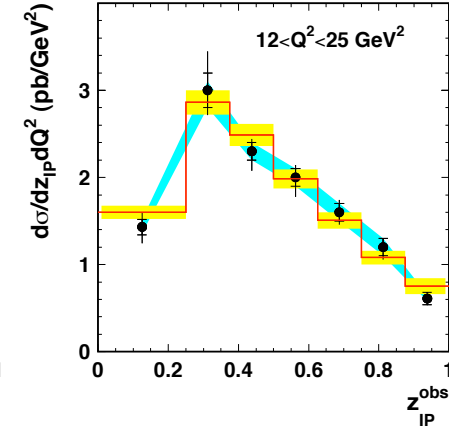
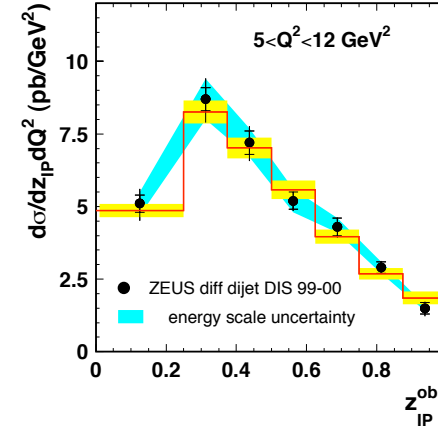
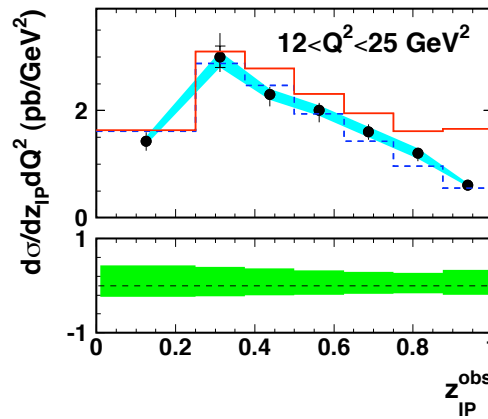
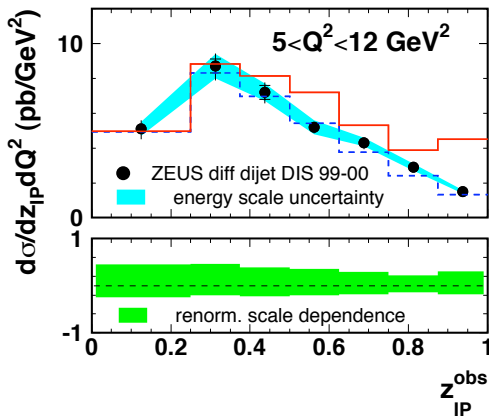
Comparison with DIS jet data



Inclusion in fit

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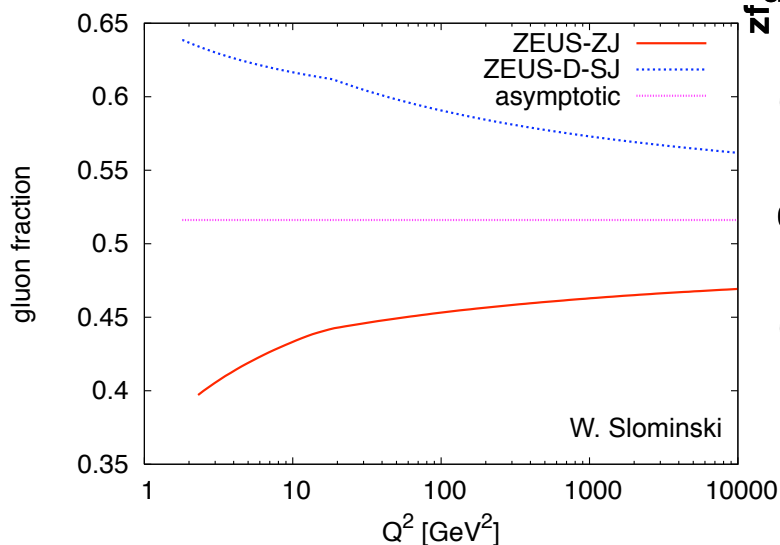
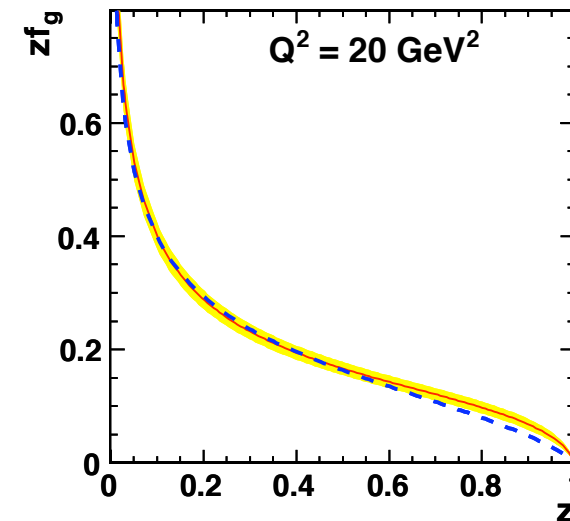
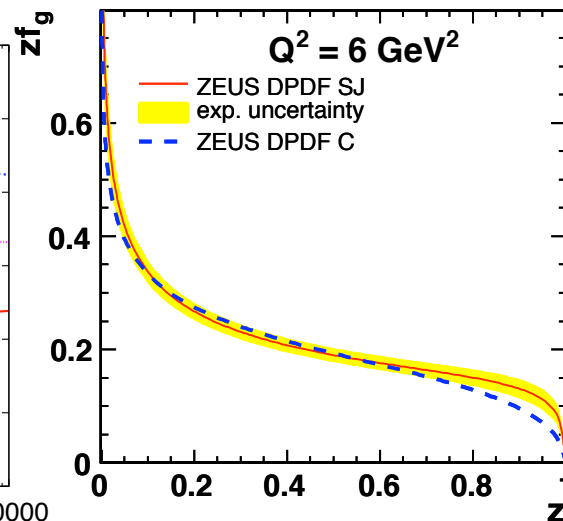
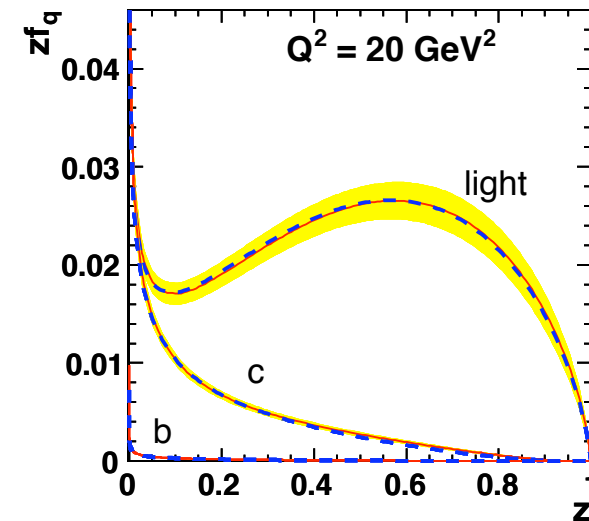
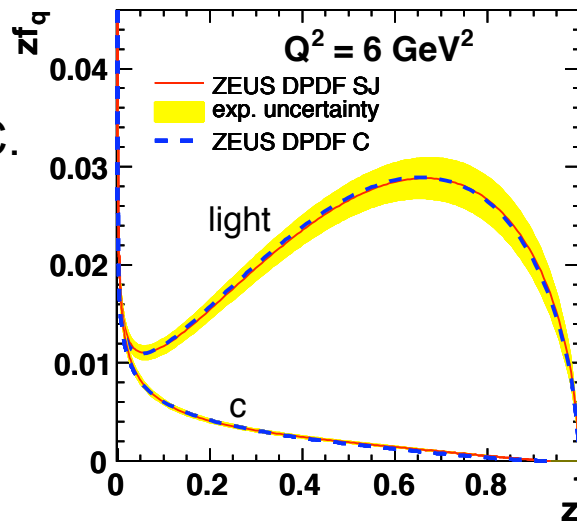


$$z_{IP} = (Q^2 + M_{jj}^2) / (Q^2 + M_X^2)$$

Resultant DPDFs including jets

- Fit C shown as reference.
- Quark distributions similar.
- Gluon distribution similar to fit C.
- Similarly good description of inclusive data.
- Much better determination of gluon density.
- Which is about 60% of the momentum of the exchange.

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Comparison with H1 DPDF

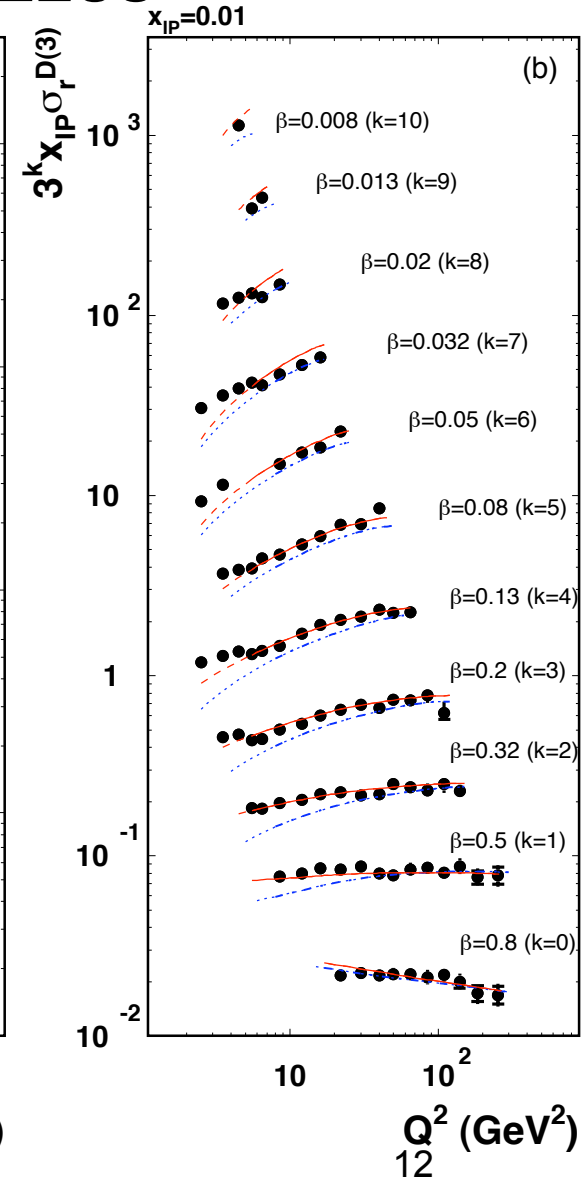
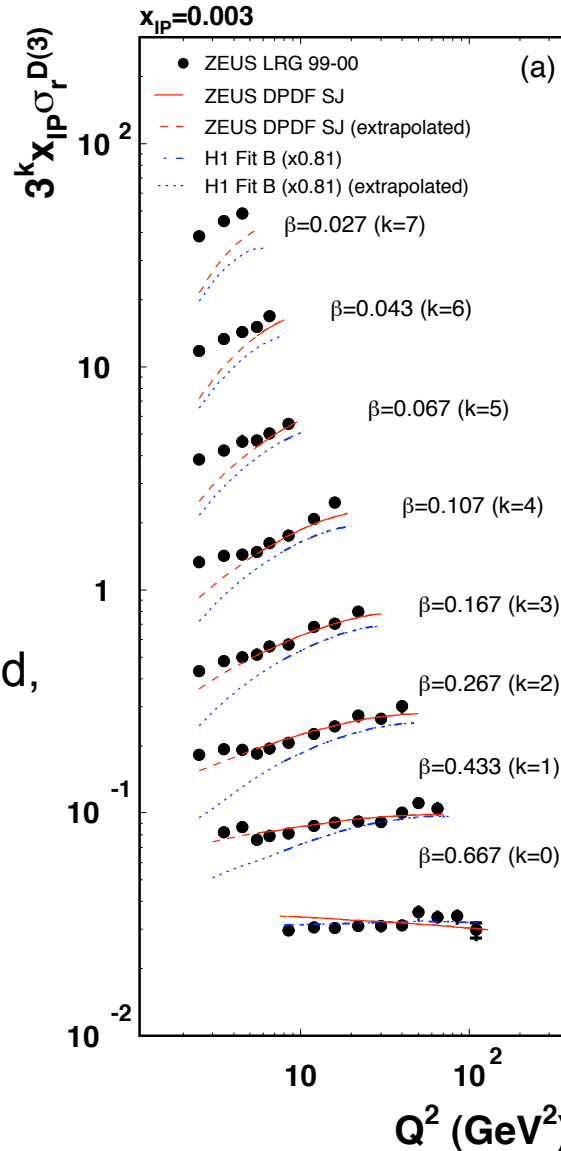
Differences ZEUS // H1 fits :

- VFNS // FFNS.
- $Q^2 > 5 \text{ GeV}^2$ // $Q^2 > 8.5 \text{ GeV}^2$.
- $M_N = m_p$ // $M_N < 1.6 \text{ GeV}$; hence scaling 0.81.

Comparison :

- Agreement in shape for $\beta < 0.2$; ZEUS fit higher.
- At higher β and where extrapolated, agreement worsens.
- Reflects degree of consistency between H1 and ZEUS data.

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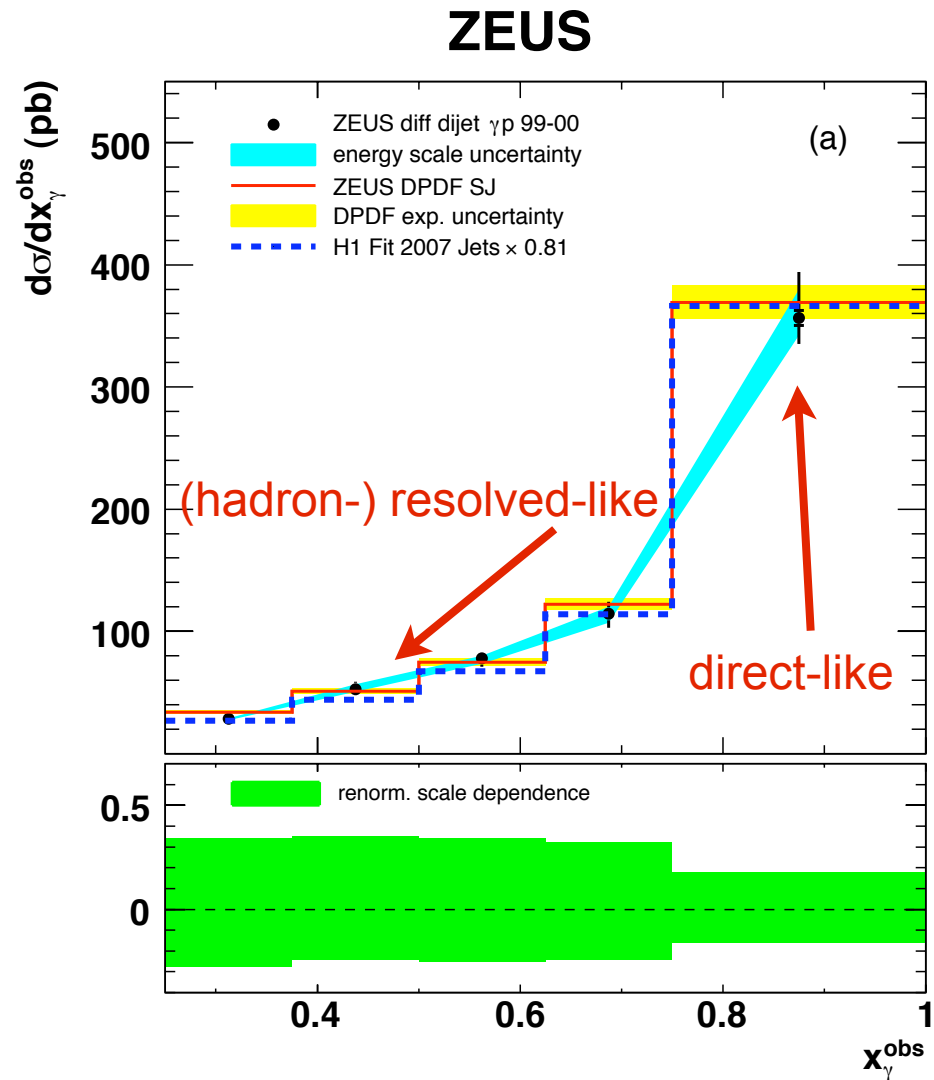


Comparison of fits with other data

To compare with independent data set and different process.

- Dijet photoproduction ($Q^2 \sim 0$) fits the bill.
- Consider the fraction of the photon's energy invested in producing the dijets.
- Reasonable description of data by DPDFs used in NLO QCD calculation.
- Difference wrt H1 Fit up to 20%.
- These data do not suggest any suppression or factorisation breaking versus x_γ^{obs} (or E_T).

• (Also compared to charm in DIS.)



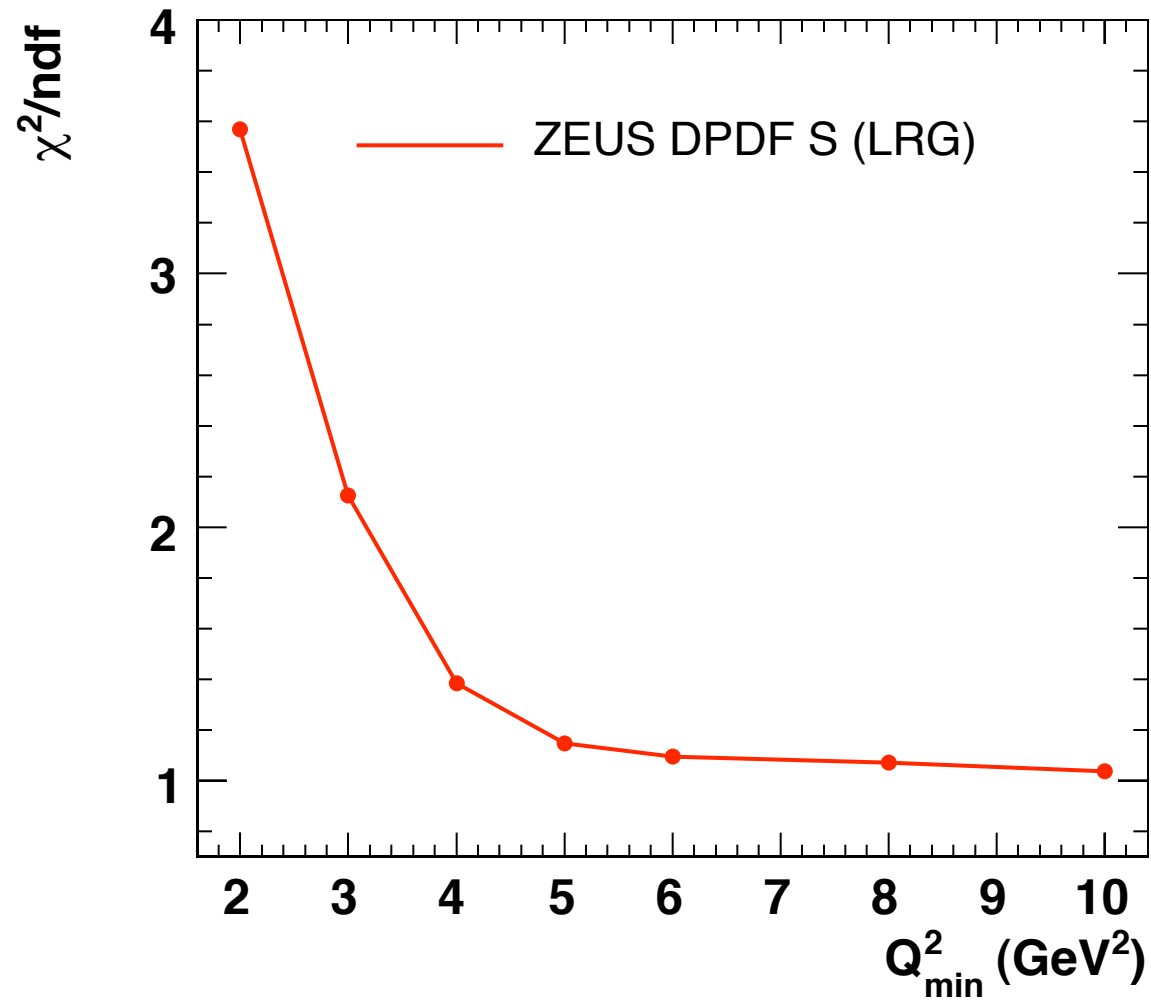
Summary and discussion

- An NLO DGLAP QCD fit to inclusive and dijet diffractive DIS data performed.
- Data well described and quark densities (from inclusive data) and gluon densities (from jet data) well constrained.
- Can predict other processes : charm in DIS and dijet photoproduction.
- Only data with $Q^2 > 5 \text{ GeV}^2$ could be fitted in the framework of DGLAP evolution and proton-vertex factorisation. Fully inclusive DIS starts at $Q^2 \sim 2.5 \text{ GeV}^2$.
- No factorisation breaking for ZEUS photoproduction data. Improved DPDFs are not going to significantly improve agreement with Tevatron data. Is picture (@ H1 / ZEUS / Tevatron) consistent ? Not necessarily inconsistent.
- Further improvements will come on detailed understanding of comparison of H1 and ZEUS data and its combination.

Back-up

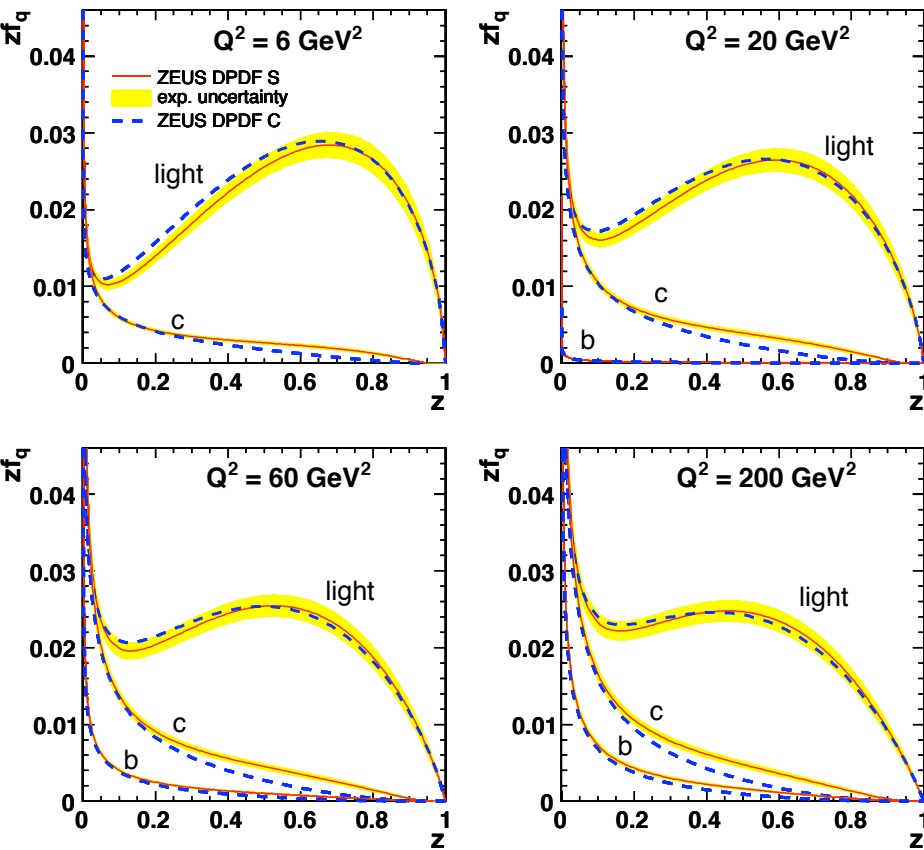
Quality of fit

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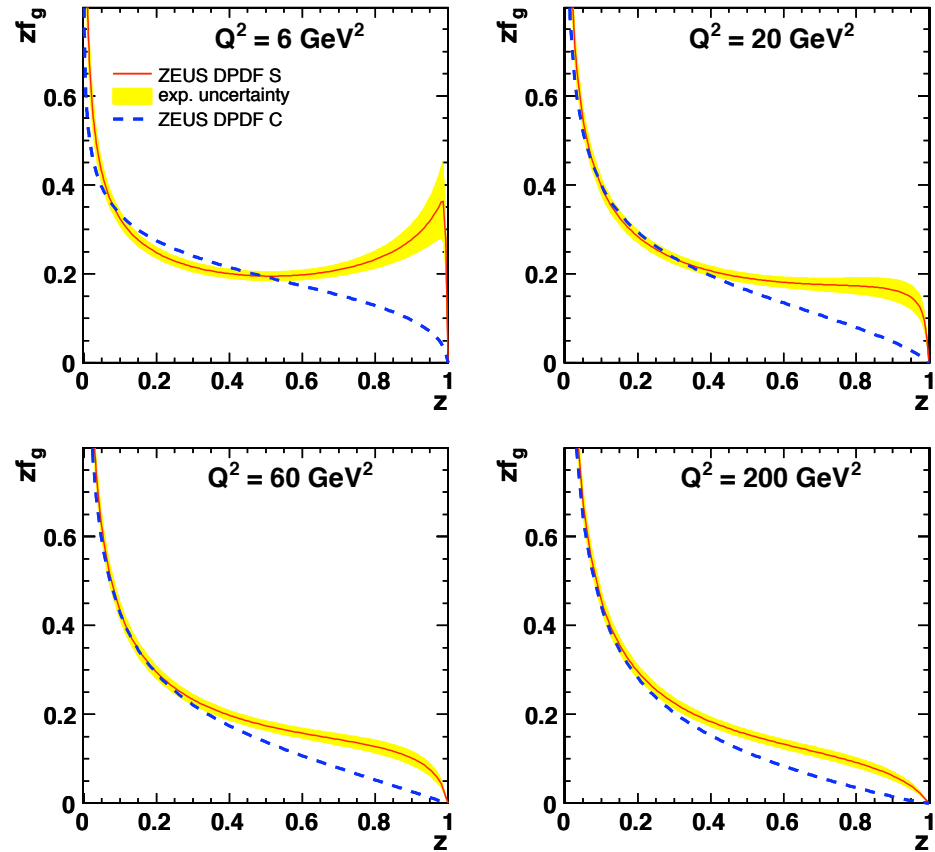


DPDFs

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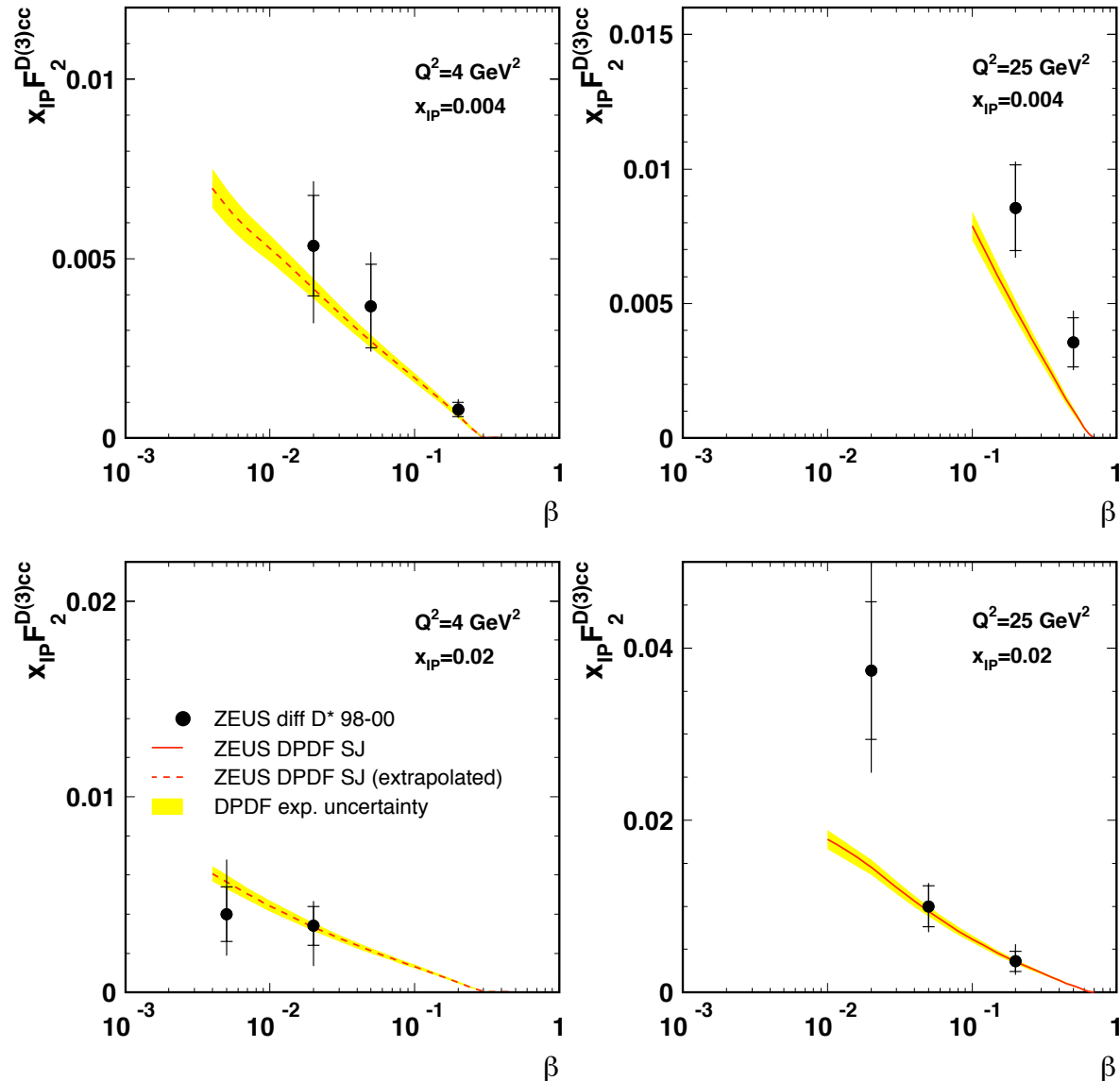
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Charm data

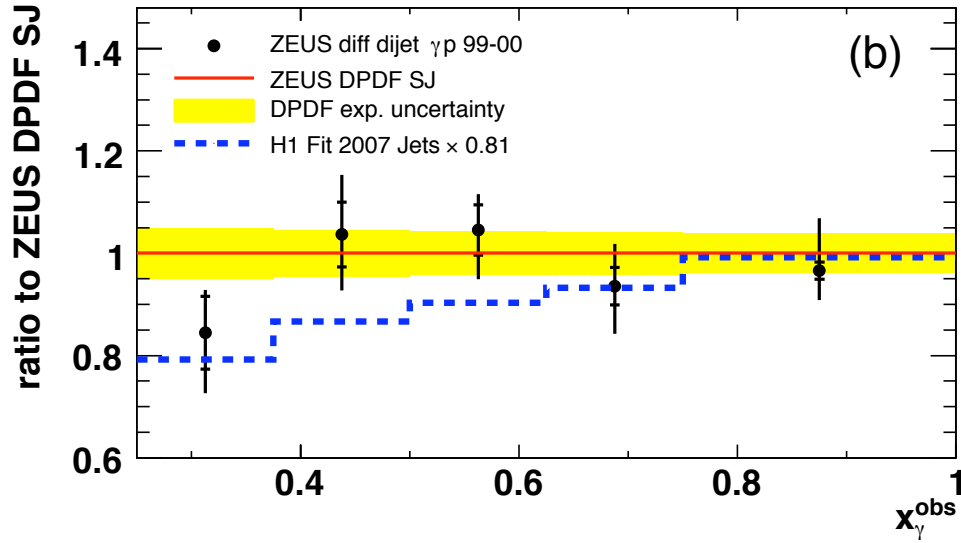
Charm contribution to the diffractive structure function

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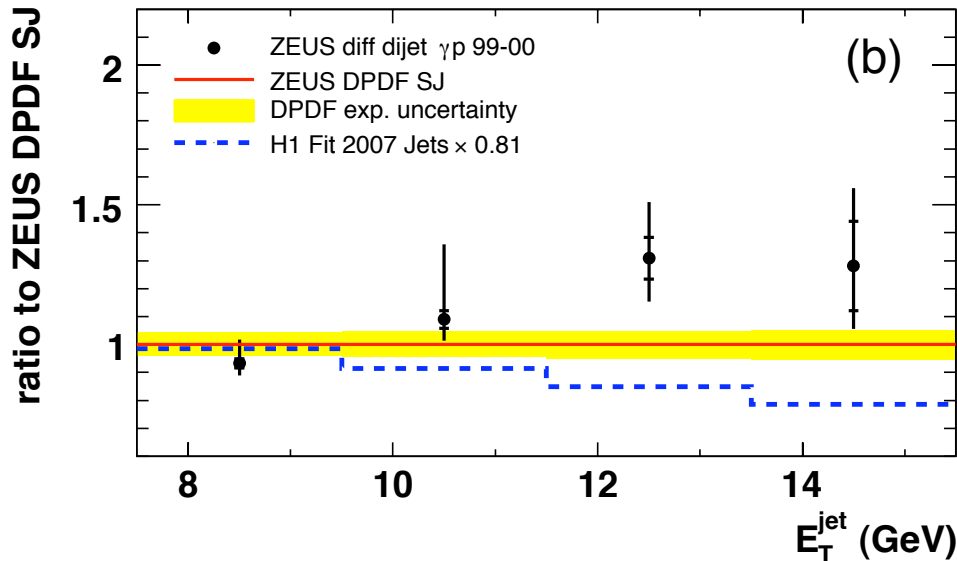


γ P jet data

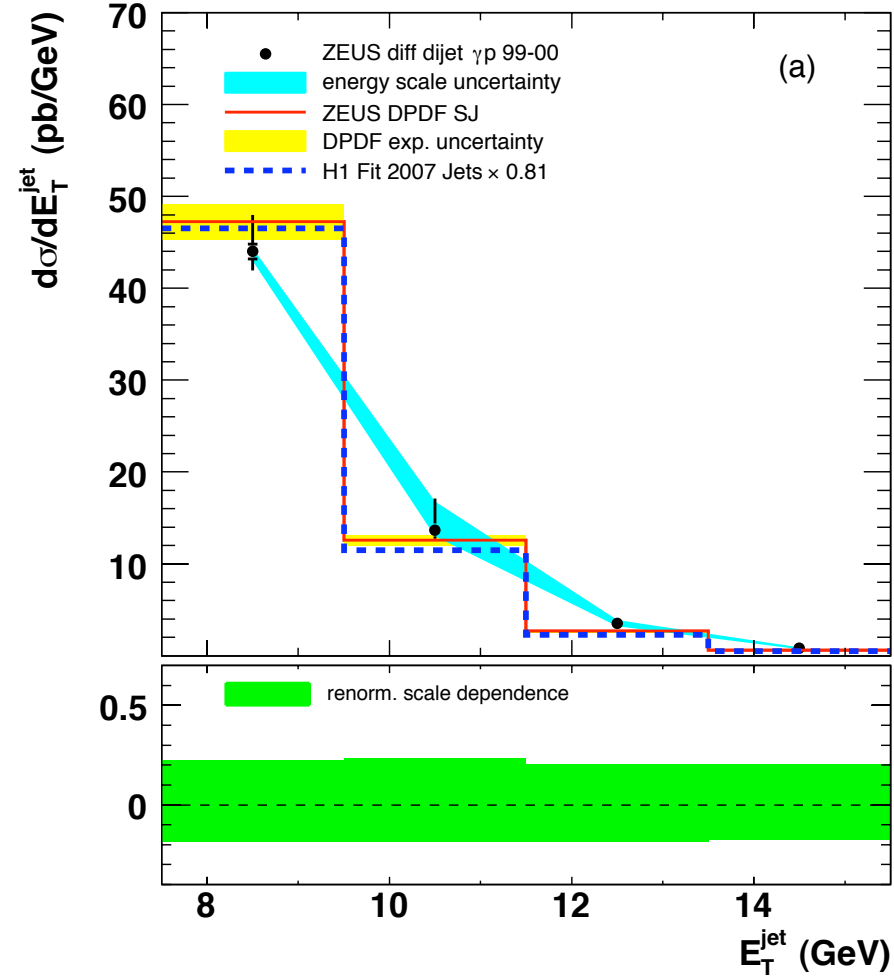
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ZEUS



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Tables of parameters

Parameter	Fixed to	Measurement	Ref.
$\alpha'_{\mathcal{P}}$	0	$-0.01 \pm 0.06(\text{stat.})_{-0.08}^{+0.04}(\text{syst.}) \pm 0.04(\text{model}) \text{ GeV}^{-2}$	[9]
$\alpha'_{\mathcal{R}}$	0.9 GeV^{-2}	$0.90 \pm 0.10 \text{ GeV}^{-2}$	[31]
$B_{\mathcal{P}}$	7.0 GeV^{-2}	$7.1 \pm 0.7(\text{stat.})_{-0.7}^{+1.4}(\text{syst.}) \text{ GeV}^{-2}$	[9]
$B_{\mathcal{R}}$	2.0 GeV^{-2}	$2.0 \pm 2.0 \text{ GeV}^{-2}$	[31]

Parameter	Fit value DPDF S	Fit value DPDF C	Fit value DPDF SJ
A_q	0.135 ± 0.025	0.161 ± 0.030	0.151 ± 0.020
B_q	1.34 ± 0.05	1.25 ± 0.03	1.23 ± 0.04
C_q	0.340 ± 0.043	0.358 ± 0.043	0.332 ± 0.049
A_g	0.131 ± 0.035	0.434 ± 0.074	0.301 ± 0.025
B_g	-0.422 ± 0.066	0	-0.161 ± 0.051
C_g	-0.725 ± 0.082	0	-0.232 ± 0.058
$\alpha_{\mathcal{P}}(0)$	1.12 ± 0.02	1.11 ± 0.02	1.11 ± 0.02
$\alpha_{\mathcal{R}}(0)$	0.732 ± 0.031	0.668 ± 0.040	0.699 ± 0.043
$A_{\mathcal{R}}$	2.50 ± 0.52	3.41 ± 1.27	2.70 ± 0.66
χ^2/ndf	$315/265 = 1.19$	$312/265 = 1.18$	$336/293 = 1.15$

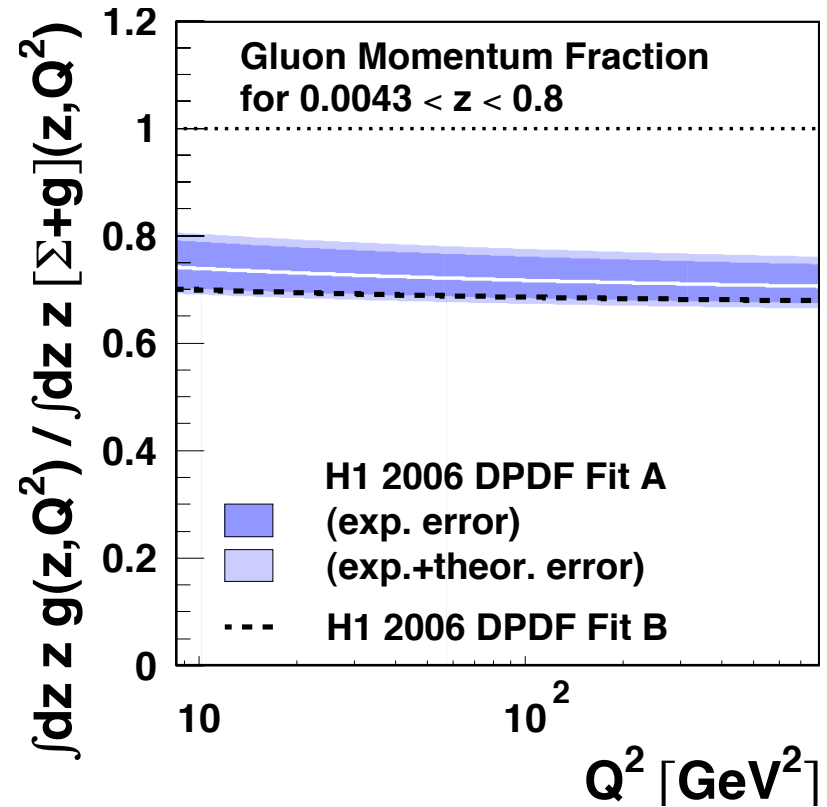
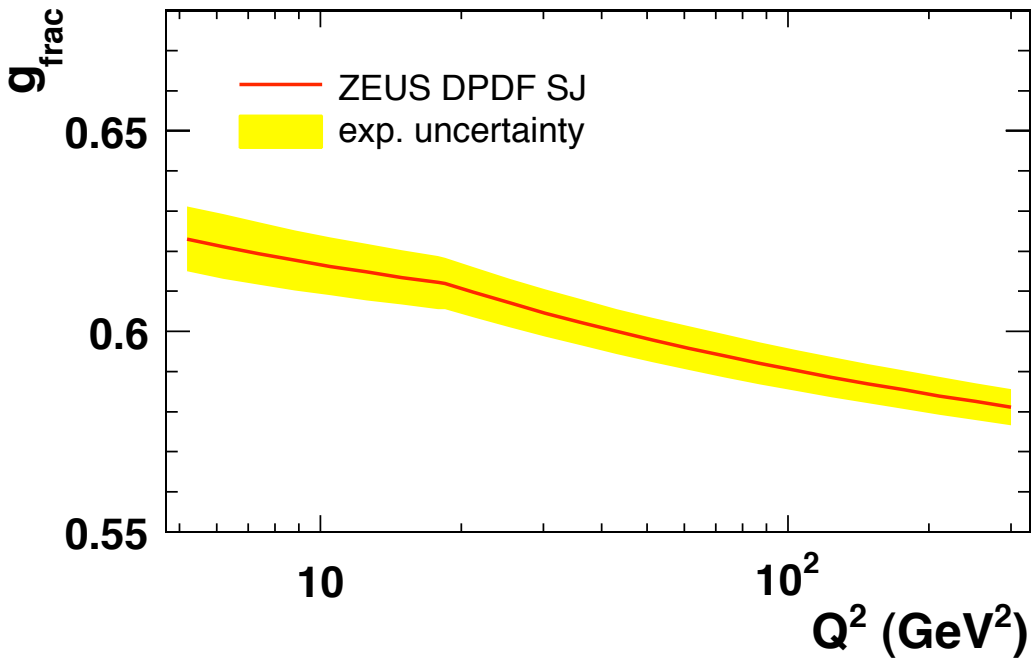
DPDF theoretical uncertainties

The following sources of uncertainties were investigated:

- the starting scale Q_0^2 . The value 1.8 GeV^2 was chosen as it minimises the χ^2 . Varying Q_0^2 for fit C between 1.6 and 2 GeV^2 yielded a χ^2 between 1.18 and 1.20 ; the DPDFs did not change significantly;
- the fixed parameters in the fits (Table 1). Variations within the measurement errors resulted in a simple scaling of the fluxes integrated over t , absorbed into the normalisation parameters A_q , A_g and A_R , with negligible effect on the DPDFs;
- the renormalisation scale dependence. The scale μ_R for dijet data was taken as $0.5E_T^{\text{jett}}$ and $2E_T^{\text{jett}}$, whereas it was kept as Q for the inclusive data. The effect on the parton densities was within 5% for light quarks, 15% for c and b and 30% for gluons, while the χ^2 increased significantly;
- the masses of the charm and beauty quarks. The nominal values of $m_c = 1.35 \text{ GeV}$ and $m_b = 4.3 \text{ GeV}$ were varied in the ranges $1.35 < m_c < 1.75 \text{ GeV}$ and $4.3 < m_b < 5 \text{ GeV}$. Neither the quark nor gluon distributions were sensitive to variations of m_b , whereas m_c produced an effect comparable to the experimental uncertainty. The χ^2 value changed only slightly, reaching the minimum at the nominal mass values.

Gluon fractions

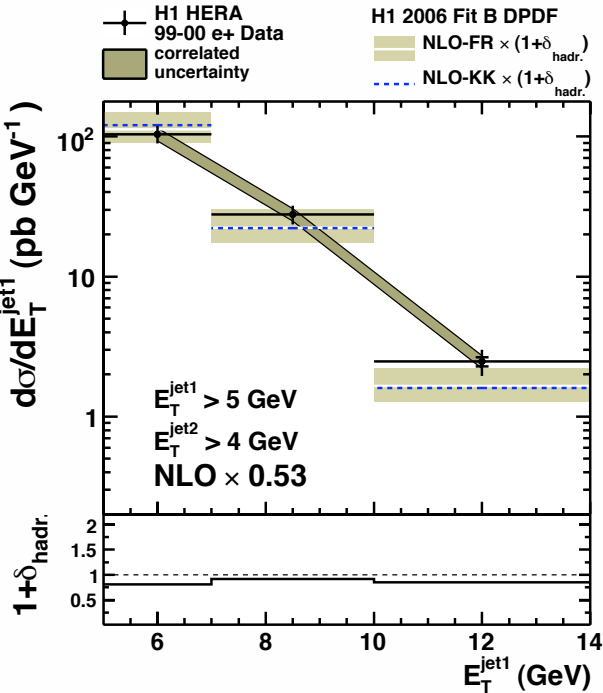
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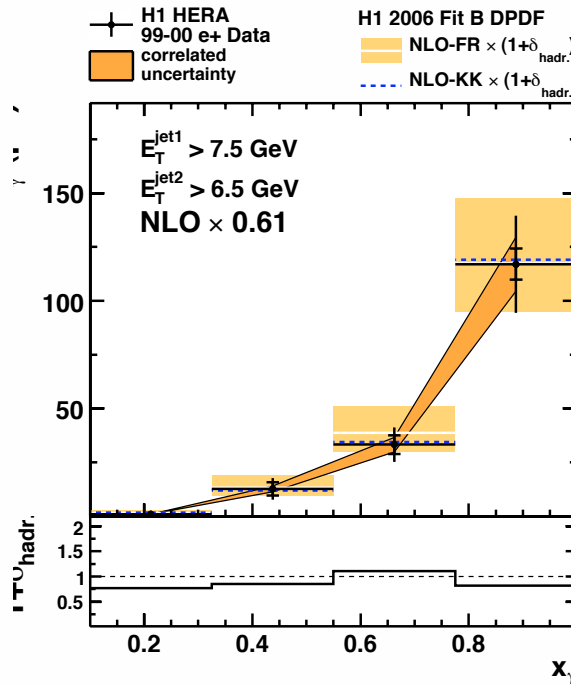
- At e.g. $Q^2 = 10 \text{ GeV}^2$,
- $g_{\text{frac}}(\text{ZEUS}) \sim 0.62 \pm 0.01$
 - $g_{\text{frac}}(\text{H1}) \sim 0.70 \pm 0.04$

H1 dijet photoproduction data

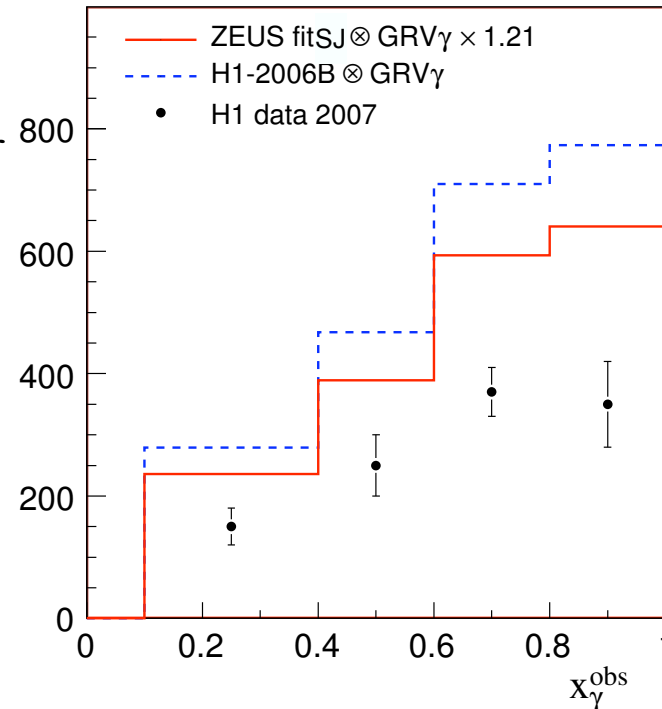
H1 PRELIMINARY



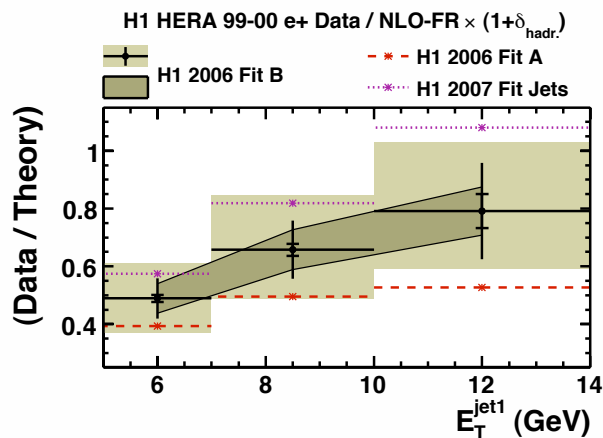
H1 PRELIMINARY



$\frac{d\sigma/dx_\gamma^{\text{obs}}}{1+\delta_{\text{hadr.}}} \text{ [pb]}$



H1 PRELIMINARY



H1 PRELIMINARY

